MUSHROOM
RESEARCH
STATION
YAXLEY
PETERBOROUGH

REPORT
for year 1953

Issued by the
MUSHROOM RESEARCH
ASSOCIATION LIMITED
YAXLEY · PETERBOROUGH
1954

PRICE: 5/-

COMMONWEALTH MYCOLOGICAL INSTITUTE
16 JUL 1954

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CHAIRMAN'S PREFACE

Growers and others associated with the Mushroom Industry were much relieved a year ago to learn there was every prospect that 1953 would be the last year they would be called upon to subscribe heavily towards the cost of maintaining research at Yaxley. In consequence it was possible to appeal with success for further finance, and mushroom experiments were continued for another twelve months.

Towards the close of the year there was an informal but significant meeting between representatives of the Toddington Board of Management and the MRA Directorate. It was a culmination of the negotiations so painstakingly conducted on our behalf by General Sir Oliver Leese, and shortly afterwards we were able to announce that the future of mushroom research was assured.

The Ministry of Agriculture would find all the money required in 1954 up to the end of September. From that date the Board of Management of the Toddington Glasshouse Crops Research Institute would be responsible. The programme at Toddington would include mushrooms, the present Yaxley programme would be continued, and the scale of research would be comparable with that of the past eight years.

Since then we agreed to 30th September being the date for the closing of the Yaxley Station. Plans are already being drafted for the erection of buildings for cropping experiments at Toddington, and it is comforting to the Industry to learn that Mr. W. H. Young, the doyen of mushroom growers in the South, is a member of the Toddington Board.

The ending of the Yaxley era is in some respects saddening, but the bold pioneering venture has succeeded in so far as mushroom research will now continue indefinitely at Toddington, where immeasurably greater resources and facilities will exist.

It is right that I should add, as a footnote, a word of appreciation to the Yaxley Staff. Through the many anxious months during which their future was insecure they continued to concentrate on the mushroom problems before them, and the Industry will join me in thanking them and wishing them well in the future, at Toddington and elsewhere.

FRED. C. ATKINS,
Chairman, 1953.

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GENERAL REPORT

The year under review has been notable for rapid developments in the use of peat and peat mixtures as casing materials. These seem to have had at least two independent origins. The use of mixtures of sphagnum peat and sand, sphagnum peat and Vermiculite, and sphagnum peat alone in some preliminary experiments was mentioned in the Annual Report for 1952, in which it was said that they might be suitable for commercial use, but much remained to be learned about their cost, preparation, and management, and about the yields to be expected. Experiments were carried out during the year in an attempt to fill some of these gaps in our knowledge, although they did not really form part of the long-term casing soil research programme. The whole question was carefully considered during the year, and the Board of the Research Association decided that the practical value of some of these mixtures, of which details have been published, was well enough established for use by growers, and that the Research Station should resume its study of the effect on cropping of the physical properties of casing materials, without requiring that the materials used should necessarily be suitable for commercial use. This policy is more likely to lead to a fuller understanding of the essential features of a satisfactory casing material and its management, which would have wider application than empirical data on one material under one set of conditions.

It will not be possible to reach any final conclusions in the short time remaining for work at Yaxley, and work on casing soil will continue at the new Glasshouse Research Institute at Toddington. The next and final Annual Report of the Mushroom Research Station will include a review of the work done since this programme started at Yaxley.

Peat for casing

Much time has been spent on the study of peat which is important both as an ingredient of experimental casing mixtures and as a commercial casing material.

Great care and attention to detail are necessary to standardise a method of wetting peat so that the same result can be repeated on every occasion. If peat is simply left in cold water it takes many days to become saturated, a process which can be made quicker by using wetting agents, applying a vacuum, or quickest of all by using hot water. Unless a standardised method of wetting and degree of wetness are established, the moisture content and behaviour of the sample on drying are not consistent from one experiment to the next.

Starting from a state of saturation, when suction is applied to the sample on a funnel the amount of water retained by the peat depends on the degree of suction applied, about twenty minutes being enough

for a state of equilibrium to be reached. By increasing the suction in stages, a moisture-suction curve can be plotted; these curves form a basis of comparison between peats, showing how much water they can hold, and how readily they give it up. But allowance must be made for differences in density of peats and such comparisons are not simple. The shape of the curve changes on repeated wetting and drying, corresponding to watering and drying on a bed, but can be made to return to its original shape again by complete immersion in water. Curves of this type are given for some samples of peat and for a mixture of peat and sand.

A practical point is that the greatest obstacle to rapid wetting of peat is the presence of trapped air bubbles. These are only slowly replaced by water if peat is left to soak, but can be dislodged quickly by compressing the peat under water, for example in a trough containing enough water to saturate the peat. It is then necessary to allow the peat to drain before casing so that water does not run out when it is placed on the bed.

Cropping experiments with peat mixtures

In one experiment with a series of peat-sand mixtures the range was not wide enough to show any difference in yield, but the next one was more successful. A mixture containing 75% of sand by weight, with sphagnum peat and Vermiculite, gave the best result ; plain peat-Vermiculite did not crop quite as well at first, and mixtures with more sand were inferior. It was also found that rather deep casing (1·8 in.) gave the best yield.

The addition of excess of hydrated lime to a peat-sand casing gave a slightly smaller number of mushrooms, but the same weight as when carbonate of lime was used. Gypsum is often added to peat, particularly sedge peat, for casing. In this experiment the addition of gypsum to a sphagnum peat-sand mixture did not improve the yield and gave slightly fewer mushrooms ; this result might not be repeated with a sedge peat in which the colloidal material, on which gypsum probably acts, is likely to be different.

In a comparison between peat-sand and peat-Vermiculite, the latter gave a slightly earlier crop but there was no difference in final yield. In this experiment there was no difference in crop between $1\frac{1}{4}$ in. and 2 in. depth of casing.

Two experiments were carried out on soils. In one of them three soil conditioners were added to Yaxley clay loam subsoil. None had any beneficial effect, and one of them gave a significantly lower yield.

In the other soil experiment three soils in regular commercial use were compared, and they were also tested with addition of sphagnum peat, which improved the yields from all three soils. It also advanced cropping on one soil but slightly delayed it on the other two.

Bed temperature measurements

One of the factors which have been suggested as possible causes of fruiting of mushrooms is a temperature difference between compost, casing soil, and air.

As a preliminary to a study of this question some accurate temperature measurements have been made using thermocouples spaced an inch apart, from the bottom of the bed through the casing to the air over it, at various stages of growth. These clearly show the local changes of temperature during heating and cooling of the house, and after such operations as casing and watering.

Disease experiments

In some experiments on disinfection, ultra-violet irradiation of low intensity was almost completely ineffective for destruction of spores, only *Mycogone* being prevented from germinating.

Dipping in 1% formalin destroyed *Mycogone* and *Verticillium* spores on wood, but not those of "spiny-spored Yellow Mould", nor eelworms or Cecid larvae. Spraying with 2% mixed xylenols and 1% formalin were not very effective methods of disinfection.

Peak heating to 120° F. with live steam killed spores of *Dactylium*, *Mycogone*, and *Verticillium* on agar plates, but did not completely destroy mites, springtails, and nematodes in compost. The total period of heating was three days, peak temperature being maintained for almost 24 hours.

Preliminary work on the bacteria found in pitted mushrooms is reported. When soil was deliberately infected with pitted mushrooms and then sterilised with formalin there was less infection of the subsequent crop than with unsterilised soil, but infection was only slight in those trays too, so the experiment was not very satisfactory.

Survey of disease

The results of a survey of commercial growers' methods and the pests and diseases found on their farms have been used to study the possible relationship between methods and results. Some of the results given in this Report are quite striking and instructive, others are less reliable, but they point the way toward methods of controlling some diseases which are closely associated with certain methods of growing.

As in previous years we offer our sincere thanks to the many people who have helped us in various ways; particularly Noble Mushrooms, Ltd., Snowcap Mushrooms, Ltd., H. Mount & Sons, Mr. E. R. Hoare and the National Institute of Agricultural Engineering, Mr. F. A. Evans, and Messrs. Vent-Axia Ltd. ; also to the Agricultural Research Council for a special grant which enabled Dr. Edwards and Miss Gandy to attend the second International Conference on Mushroom Science in Belgium.

CHEMISTRY DEPARTMENT

P. B. Flegg

Advisory work

The number of samples received continues to increase steadily ; this year 70 were dealt with. In previous years the samples were mainly soils or composts. This year however a number of peats and peat mixtures were submitted, reflecting the interest of the growers in ' artificial ' casing materials.

Casing soil

During the year 14 samples of casing soils were obtained from growers in various parts of the country, so that some of their physical properties could be compared. All were in regular use and were therefore capable of giving commercially adequate yields under suitable management. In view of the other variations between the farms from which they came it was not considered worth while trying to compare the yields normally obtained with these soils. The main properties measured were water holding capacity, pore space, state of aggregation and stability to water.

The pore space before and after settling was determined as described in the previous report (Flegg, 1953). Before settling, the pore space was over 60% with the exception of two fine sandy soils which had 44% and 51% pore space. The effect of settling by tapping was to reduce the pore space to between 50% and 60%. The two sandy soils were reduced to 37% and 45% pore space respectively. Thus most of the soils had a fairly high pore space.

One of the sandy soils is used to case ridge beds in caves, while the other is used on shelf beds, with some peat added.

Water holding capacity, determined by a gravity drainage method, was generally over 30% by volume. Exceptions to this were two clay soils which contained a high proportion of stones and ashes.

The use of a suction method, described previously (Flegg, 1951) gave somewhat different results, with a low water holding capacity for the sandy soils. It is to be expected that there would be differences between the two methods. The gravity drainage method is carried out upon the soil as received, whereas for the suction method it is ground to pass a 2 mm. sieve and stones, etc., are removed.

The water stability of the soils varied considerably. Some soils were very unstable to water, while the stability of others was good. There was great variation in the results of dry and wet sieving.

On dry sieving soils ranged from—

30% over 2 mm. and 60% under 0·2 mm.
to 88% over 2 mm. and 1% under 0·2 mm.

Some soils with 60-80% over 2 mm. dry, retained 40% of this coarse material after wet sieving, whereas others broke down to give less than 1% over 2 mm. on wetting.

Soils with a very high proportion of fine aggregates (under 0·2 mm.) had a high water holding capacity by the drainage test, but gave up a substantial proportion of this water in the suction test (e.g. drainage test 44·7%, suction test 26·5%). In three soils with over 40% of material over 2 mm. on wet-sieving, there was no appreciable difference in water holding capacity observed by the two methods (drainage test 27·9%, suction test 29.8%).

Breakdown of soil structure in water is thus not an insuperable weakness of a casing soil, though it may make growing more difficult, and soils with a wide range of aggregate size distributions can be used. Some appear to be easier to manage than others.

The water holding properties of peat

In the Annual Report for 1952, the water holding and related properties of several mixtures of sphagnum peat, clay, sand, etc., were reported. These figures were obtained by a routine gravity drainage method. The results obtained by this method are sometimes not very consistent but are sufficient to show large differences between mixtures. Several anomalous results were obtained but were not investigated further. In order to study the properties and behaviour of these materials more closely, a more accurate method is necessary. The object of the work is to examine the waterholding characteristics of several types of peat and peat mixtures with particular reference to the absorption and retention of water.

Some of the difficulties encountered when measuring the water holding properties of peat are due to its compressibility. The weight of peat which may be packed into a given volume varies considerably. This is one reason for the great variations found with the gravity drainage method. It is therefore necessary to control the extent to which the peat is packed. To obtain more information on the manner in which peats take up and hold water, the amount of water held against several suction pressures is being investigated.

The procedure is to soak a known weight of peat in a large beaker of cold water, with occasional stirring, for a given time. The wet peat is then packed into a 200 ml. Buchner funnel, drained, weighed and subjected successively to suction pressures of 10, 20, 50, 100 cm. water and 23.3 cm. mercury corresponding to pF values of 1·0, 1·3, 1·7, 2·0, and 2·5. A Whatman No. 5 filter paper in the Buchner funnel prevents loss of peat during suction. The period of suction at each pressure is 30 minutes. At the end of the suction period the rate of loss of water is less than 1 drop per minute. By weighing after suction at each pressure the amount of water held can be calculated. In order to reduce the loss of water by evaporation the air passing through the peat during suction is previously moistened and losses from this cause are negligible.

It has been found that the results obtained depend to a great extent upon the degree of saturation of the peat. Two duplicate samples of peat wetted by immersion in water do not necessarily reach the same degree of saturation in the same time. This is a cause of variation between duplicates. To obviate this difficulty it was decided to use the same

Figure 1—Moisture-suction curves: sphagnum peat 12·5g/100 ml.

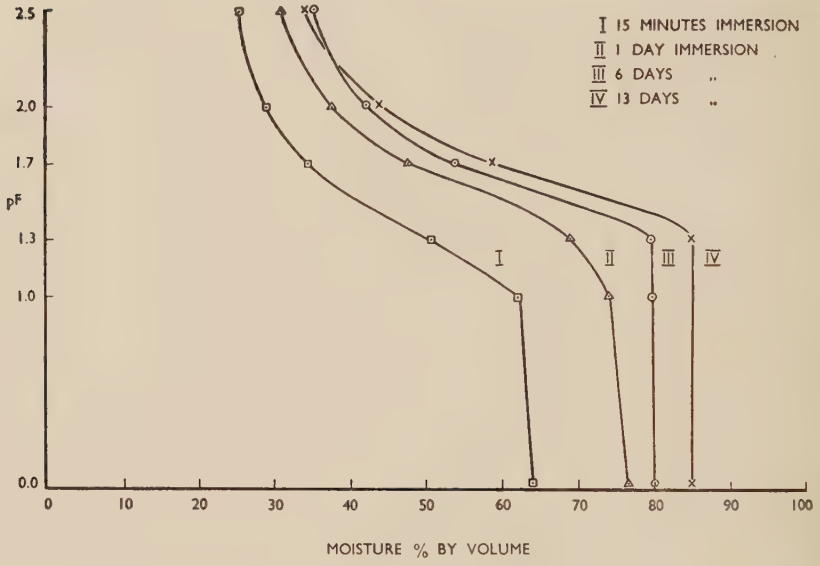
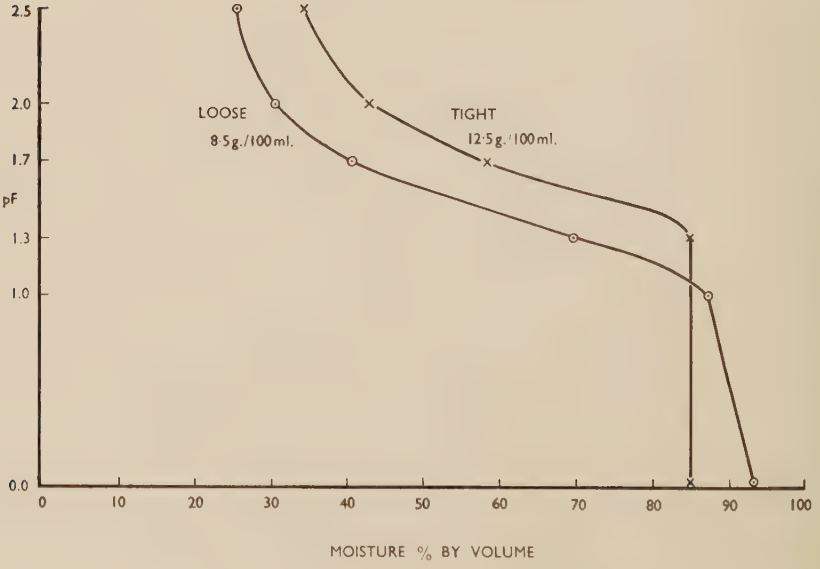


Figure 2—Moisture-suction curves: sphagnum peat loosely and tightly packed



sample of peat throughout a set of determinations. Thus after the first soaking and subsequent suction the peat is returned to the beaker for further soaking. Although this gives no measure of the variability of the peat, a continuous record of the wetting of the peat over several days is obtained (Fig. 1).

The peat is considered to be completely saturated when none of it remains floating on the water. This stage was reached in 12 to 14 days with most peat samples examined, but somewhat earlier with a finely ground sedge peat.

The moisture-suction curves obtained with a sample of fibrous sphagnum peat from Germany packed at 12·5 g./100 ml. after increasing periods of immersion are shown in Fig. 1. The shape of each curve depended upon the degree of saturation of the peat at the time of measurement. This was found to be the case for all of the peat samples examined. There is therefore no one moisture-suction curve which can be said to be characteristic of a particular peat sample. Several curves can be obtained from the same peat, each depending upon the packing and degree of saturation. In order to make comparisons it is therefore necessary to ensure equal packing, not necessarily the same weight of peat per unit volume, and the same degree of saturation. So far, work on the problem of obtaining a more exact measure of equal packing has not been completed. It is therefore not yet possible to compare accurately the water holding properties of sedge and sphagnum peats. The effects of tight and loose packing of sphagnum peat are shown ; all other treatments were carried out on sphagnum peat packed at 12·5 g./100 ml. The weight of peat given in packing measurements refers to the oven dry weight of peat per 100 ml. calculated from a separate moisture determination.

Fig. 2 shows the curves obtained with a fibrous sphagnum peat packed loosely (8·5 g./100 ml.), and tightly (12·5 g./100 ml.). In each case the peat was completely saturated. The peat which was loosely packed held a slightly higher volume of water at tensions less than pF 1·0, but at higher tensions the tightly packed peat held most water. Compressing the peat seems to alter the pore space size distribution, a greater proportion of smaller pores would account for the greater volume held by the more tightly packed peat at the higher tensions.

The effect of watering (Fig. 3) has been simulated by saturating the peat completely and after obtaining the moisture-suction curve I re-wetting the peat from above while still in the Buchner funnel. Another moisture-suction curve was then obtained and the peat again re-wetted in situ. This was repeated several times (curves II, III and IV). Fig. 3 shows that the amount of water taken up and held at tensions up to pF 1·3 decreased after each re-wetting. Finally, after complete immersion overnight, the moisture-suction curve closely resembled curve I. Thus watering from above was not sufficient to re-saturate the peat completely. This indicates that when peat was partly dried and then re-wetted by liberal watering on the funnel some air remained trapped in the peat and maximum saturation could not be attained. During the

immersion of peat in water it was noticed that many small air bubbles were present until the peat was completely saturated. At this stage there were no bubbles and no peat remained floating. A few preliminary tests confirmed that the rate of wetting of the peat is increased by immersing in water under reduced pressure in a vacuum desiccator. This facilitates the escape of the trapped air bubbles.

It was also noticed that peat when boiled for a short period sank completely, all the trapped air having been removed. A sample of sphagnum peat was boiled for 10 minutes, cooled and a moisture-suction curve obtained. The curve obtained was almost identical with a curve obtained from the peat soaked by immersion in water for 13 days (Fig. 4). Boiling for 10 minutes appeared to have no adverse effect upon the peat and considerably increased the rate of wetting. Thus the main obstacle to the absorption of water by peat is the presence of trapped air.

The moisture-suction curves obtained from three grades of a Somerset sedge peat are shown in Fig. 5. The grading was carried out by passing through screens having circular holes $\frac{1}{8}$, $\frac{3}{8}$ and $\frac{5}{8}$ inch in diameter. Grade A, $\frac{1}{8}$" particles, was completely saturated within five days. There is less possibility of air bubbles becoming trapped in a finely ground peat. The coarser grades B, $\frac{1}{8}$—$\frac{3}{8}$ in, and C, $\frac{3}{8}$—$\frac{5}{8}$ in. took 13 days to become completely saturated.

Figure 3—Moisture-suction curves: sphagnum peat 7g./100ml. effect of rewetting in situ

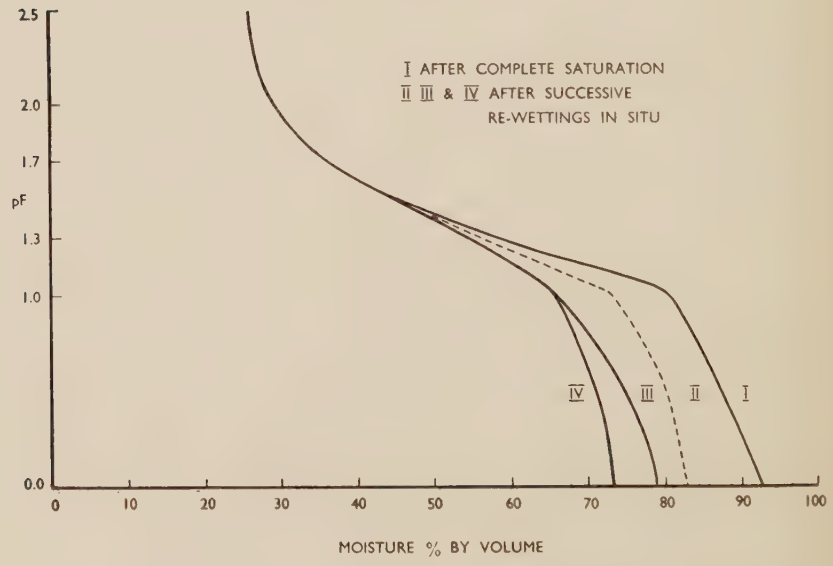


Figure 4—Moisture-suction curves for sphagnum peat 12·5g./100ml.

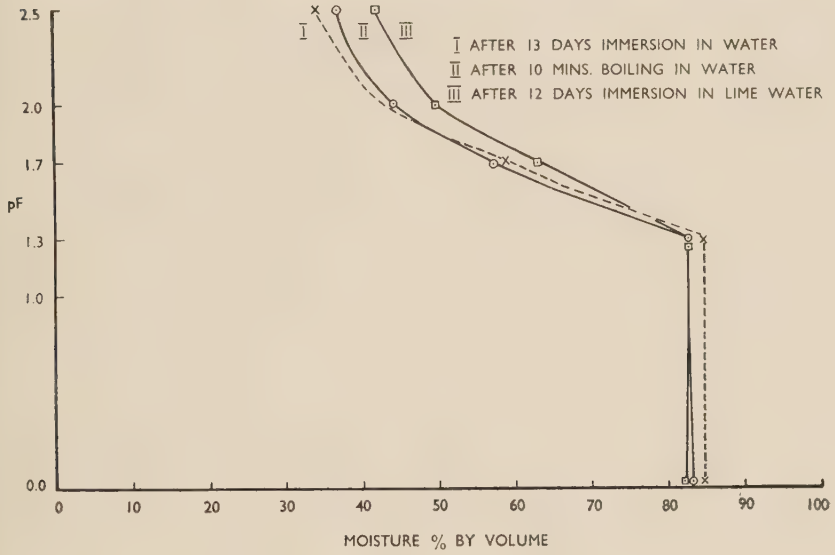
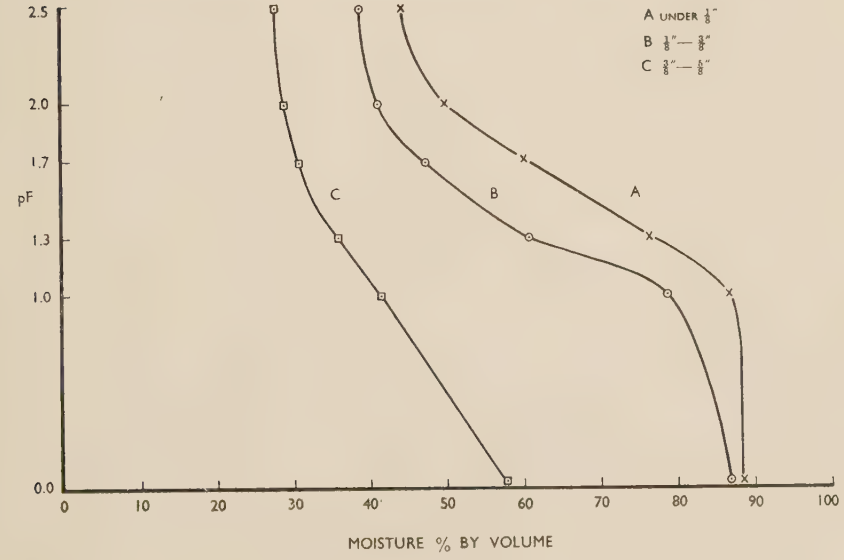


Figure 5—Moisture-suction curves for a sedge peat

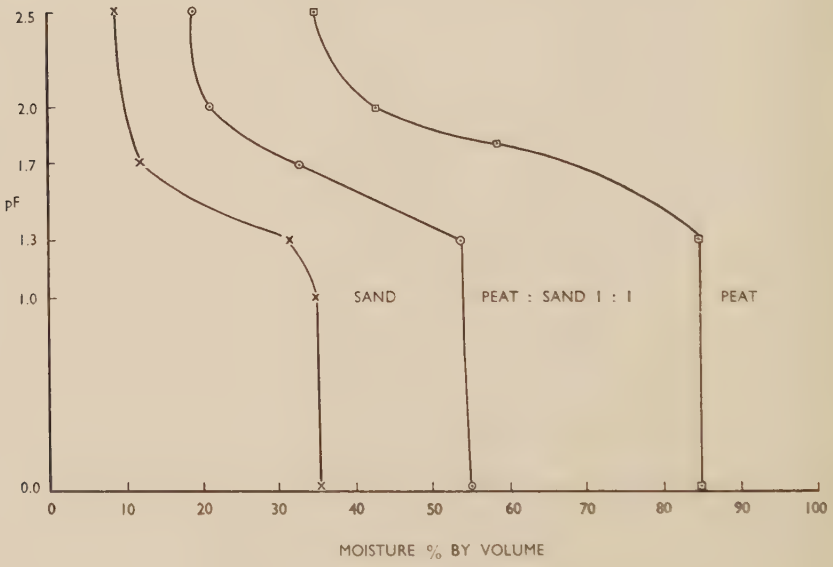


There are considerable differences between the curves obtained. The packing was judged to be about the same for each grade, being 20 g./100 ml. for grade A, 21 g./100 ml. for grade B, and 14 g./100 ml. for grade C. The coarse grade, C, was made up of fairly large hard pieces of peat with a little fibrous material. The lower water holding capacity of this peat was due not only to the fact that less peat was present but also that there were many air spaces which were too large to hold water. This applied to a lesser extent to grade B.

The peats used in the preceding experiments were unlimed. As it is necessary to add lime to peat in practice the possible effects of lime upon waterholding properties were considered. Fig. 4 shows the moisture-suction curve obtained from sphagnum peat saturated by immersion in a saturated solution of calcium hydroxide and that obtained from peat saturated in water. At the lower suction pressures there was little difference but above pF 1·7 the lime-treated peat held slightly more water.

Although most of the work so far has been carried out with peats, one sand and sphagnum peat mixture 1 : 1 by volume has been studied. The curves for this mixture, and for sand and peat alone are shown in Fig. 6. The curve for the mixture was approximately mid-way between the peat and sand curves.

Figure 6—Moisture-suction curves for sphagnum peat and sand



This investigation of the water holding properties of peat and similar materials is still in progress but the observations made so far may be summarised:

1. The moisture-suction curves obtained by this method are dependent upon the packing and initial degree of saturation of the peat. Before comparisons can be made the packing and degree of saturation must be the same for each sample.

2. To reach the stage of complete saturation usually takes about 12—14 days immersion in cold water with occasional stirring. Boiling in water for a short time saturates the peat completely without any apparent detrimental effect upon the water holding properties.

3. The main obstacle to complete saturation of the peat is the presence of trapped air. Procedures which facilitate the removal of this air reduce the time required to reach complete saturation.

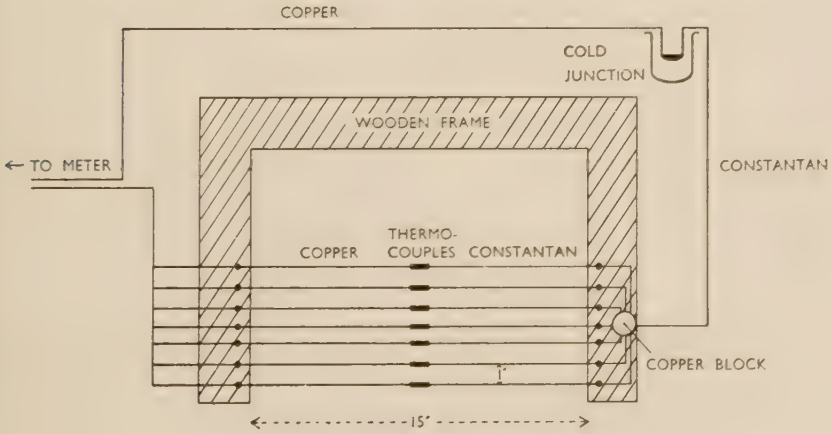
4. There is some evidence that the addition of lime alters the water holding properties of sphagnum peat; this requires further confirmation.

Some observations of bed temperature changes throughout the cropping cycle

With the help of the National Institute of Agricultural Engineering apparatus was set up to measure the temperature in a mushroom bed at 1″ intervals throughout its depth. Temperatures were measured to the nearest 0·1° F.

The apparatus, which is shown in Figure 7, consists of seven copper-constantan thermo-couples mounted at vertical intervals of 1″ on an upright wooden frame. The thermo-couples are connected to a copper block which is fixed to the frame and when in position is in the centre of the compost. The temperature of the copper block is first determined by switching into series with a cold junction (melting ice).

Figure 7—Apparatus for measurement of bed temperatures



Using the copper block as a reference the differences in temperature between the thermo-couples and the copper block are then found by switching each in series with the copper block in turn.

Temperature measurements have been made with this apparatus at several stages of the cropping cycle.

During spawn run: A typical set of readings for one day are shown in Fig. 8. The house temperature at this time was rising during the day and falling during the night. After the overnight cooling, at 10 a.m., the lowest temperature was at the compost-air surface. As the house air temperature rose the temperature at the compost surface rapidly increased while the compost beneath the surface continued to cool. Similarly in the evening it was found that the temperature of the compost continued to rise after the air temperature had commenced to drop. The compost next to the bed boards and at the top surface responded more readily to external air temperature changes than that in the centre of the bed. This is to be expected. The spawn run in this bed was good and no effect due to the growth of the spawn was observed.

At casing: On the two occasions when observations were made the soil was applied at a temperature much lower than that of the beds. The effect of placing this cold layer of soil on the compost is shown in Fig. 9. About 30—45 minutes after casing the temperature in the compost 1″ below the soil had dropped 0·8° F. The temperature of the compost deeper than 2″ was not affected by the cold soil and continued to rise. However, within the next 1—2 hours the temperature

Figure 8—Temperatures throughout bed : during spawn run

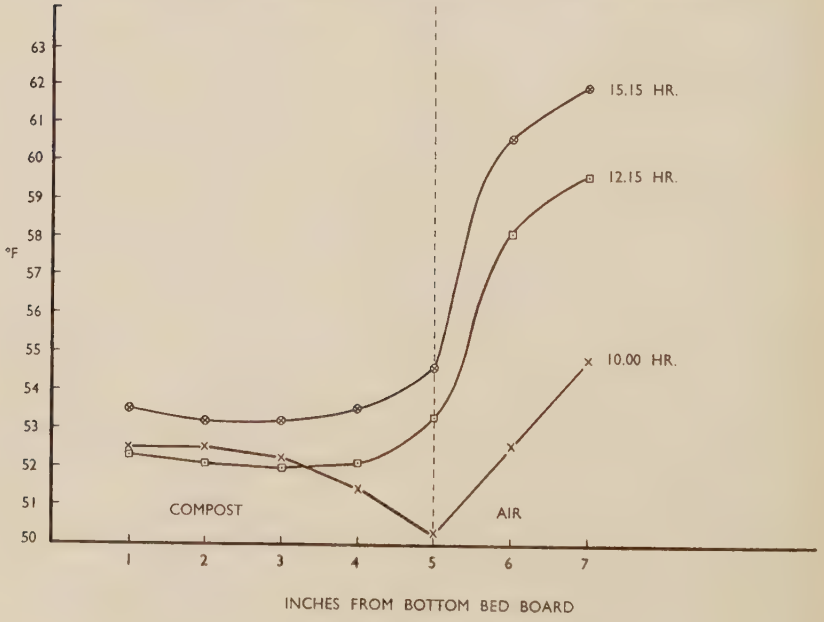
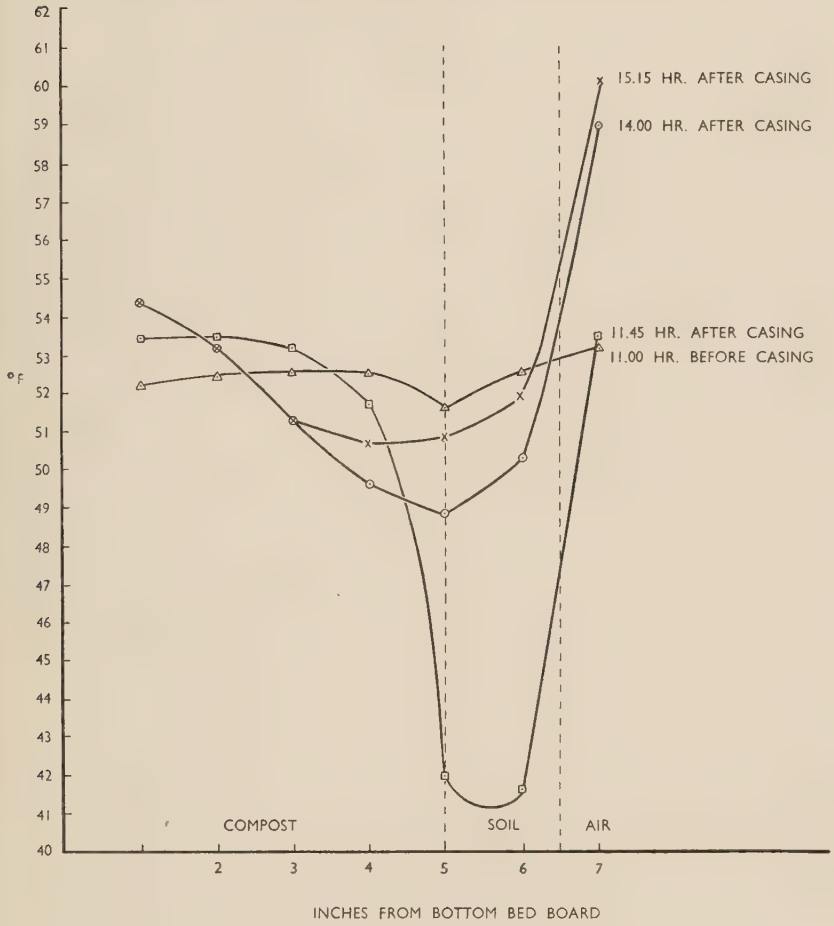


Figure 9—Temperature throughout bed : at casing



dropped almost throughout the compost so that a definite temperature gradient existed. In the case shown, the house air temperature rose steadily throughout the day and by the next morning temperature conditions had returned to the normal pattern.

After casing: The presence of the soil appeared to have little effect upon the temperature characteristics of the bed. After a cold night the lowest temperature was found at or near the soil surface instead of the compost surface. This is shown in Fig. 10. The ready response of the bed bottom and surface to external temperature changes is shown clearly in this graph.

Figure 10—Temperature throughout bed: after casing

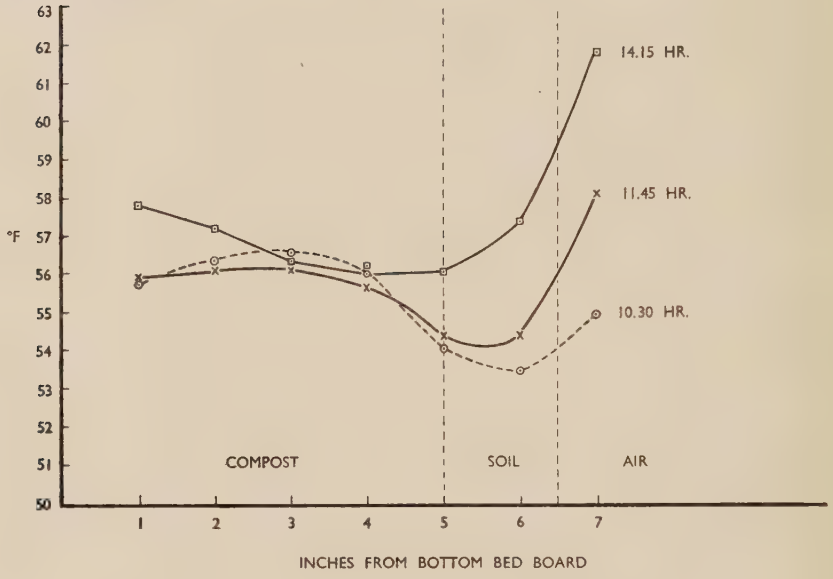
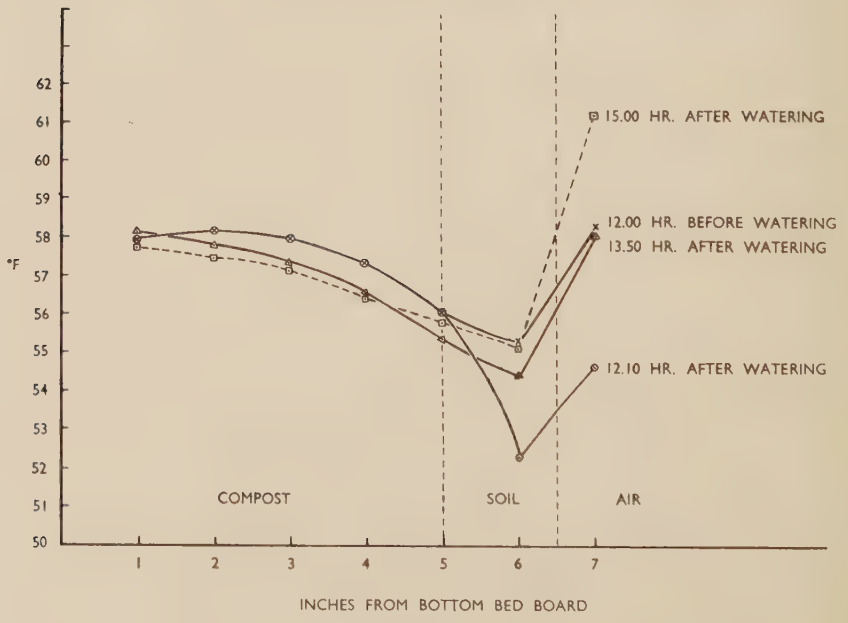


Figure 11—Temperature throughout bed: at watering



At watering: The application of cold water to the soil had little effect upon the compost temperature. (Fig. 11.) The soil temperature dropped only 3° F., when the temperature of the water was over 10° F. cooler than the soil before watering. The drop in the compost temperature was much less and took place over a longer period of time. Changes in house temperature are likely to have a much greater effect on compost temperature than watering the soil.

No differences in temperature due to the growth of mycelium or fruiting bodies have been detected.

Similar sets of readings were taken on a bed cased with a 1 : 1 mixture by volume of peat and vermiculite. There appeared to be no outstanding differences between this casing and soil.

Addition of compost to casing soil

In order to obtain more information on the function of soil as a casing medium and the fact that beds will not fruit to any extent unless cased with a suitable medium, two experiments were set up in which trays were cased with several soil-compost mixtures.

The trays of 3 sq. ft. were filled and spawned in the normal way and in the first experiment were cased as follows:—

A soil alone
D soil : compost 3 : 1 by volume
B soil : compost 2 : 1 by volume
C soil : compost 1 : 1 by volume

The soil was the normal Yaxley clay loam subsoil and the compost was part of a batch of synthetic which had been used to fill a house and peak-heated. There were four trays in each treatment.

The cropping data are given in Table 1. Both B and D mixtures gave a significantly higher weight of mushrooms than the trays cased with soil alone A, while the mixture C containing equal volumes of soil and compost gave a significantly lower yield. Mixture D also produced many more mushrooms than A, there was no difference between the number of mushrooms produced by treatments A and B. Mixture C produced the lowest number of mushrooms and was late in coming into crop.

Table 1. Soil-compost casing mixtures

Casing mixture Soil : Compost % by volume		First pinheads Days from casing	First picking	8 weeks cropping per tray	
				No.	oz.
A 100		30	40	58	23·7
D 75	25	31	42	89	25·9
B 67	33	32	41	63	26·3
C 50	50	37	46	49	21·6
				±3·1	±0·7

Thus addition of up to one-third by volume of compost to the soil increased the weight of mushrooms produced, but addition of a quarter by volume affected the size of the mushrooms. This increase in yield was unexpected and may be due partly to the effect of the compost in increasing the pore space of the soil. It was calculated that the pore space of the soil when dry was 57% and that of the mixtures D and B 65% and 71% respectively. It is also possible that the mixing of soil and compost increased the area of contact between soil and mycelium.

Where the proportion of compost was high, mixture C, the mycelium permeated the casing to such an extent that watering became difficult, as most of the water applied would not soak in and ran off the surface.

In the second experiment the proportion of compost was increased. The mixtures were:—

P soil alone
Q soil : compost 1 : 1 by volume
R soil : compost 1 : 3 by volume
S compost alone

The cropping data are given in Table 2. No statistical analysis was considered necessary, all of the mixtures containing a high proportion of compost produced very much lower yields than the soil alone, and the trays cased with compost alone did not yield at all. The watering of mixtures Q, R and S was very difficult, once the casing was permeated with mycelium water was not absorbed to any extent.

In most casing soils the mycelial growth appears generally less dense than in compost, and it is possible to keep a moist layer over the top of the bed. This was not possible in these experiments where the proportion of compost in the casing was high because of the dense mycelial growth. This may account for the reduced yields. Mycelial growth in peat casings is not too dense to prevent satisfactory watering to be carried out.

These experiments confirm the need for a casing medium which can absorb and hold water so that it is available to the mushroom. The admixture of a certain amount of compost with the soil may be beneficial but the reasons for this are unknown.

Table 2. Soil-compost casing mixtures

Casing mixture Soil : Compost % by volume		First pinheads Days from casing	First picking Days from casing	8 weeks cropping per tray	
				No.	oz.
P 100		22	28	60	52·2
Q 50	50	21	28	17	19·0
R 25	75	37	50	3	4·2
S	100	—	—	0	0

CROPPING EXPERIMENTS

R. L. Edwards

In **Experiment 23** three soils in regular use for casing mushroom beds were used, each (*a*) alone and (*b*) with 10% by weight of sphagnum peat. Carbonate of lime was added, 1 lb. to 5 lb. of peat, and 1 lb. to 1 cwt. of soil. The soils were:

Yaxley clay loam subsoil dug at the Research Station.

A silty soil from Selby, Yorks.

A fen soil from Wisbech, Cambs.

The results are given in Table 3.

Table 3. Results obtained with three soils and peat

Soil	Yaxley	Selby	Wisbech	
Soil used plain				
First pinheads	68	64	64	±0·6 days from spawning
First picking	76	74	75	,, ,, ,,
Fruiting—				
4 weeks	10·3	13·2	6·3	mushrooms/sq. ft.
final (12 weeks)	19·9	25·2	11·7	±1·2 ,,
Yield—				
4 weeks	10·4	11·2	5·8	oz./sq. ft.
final (12 weeks)	15·9	17·9	8·5	±0·5 ,,
Average size—				
4 weeks	1·01	0·85	0·92	oz./mushroom
final (12 weeks)	0·80	0·71	0·73	,,
Soil used with peat				
First pinheads	66	66	65	±0·6 days from spawning
First picking	75	75	75	,, ,, ,,
Fruiting—				
4 weeks	17·5	19·8	12·2	mushrooms/sq. ft.
final (12 weeks)	33·2	34·8	20·4	±1·2 ,,
Yield—				
4 weeks	13·3	15·5	11·2	oz./sq. ft.
final (12 weeks)	20·3	22·7	15·2	±0·5 ,,
Average size—				
4 weeks	0·76	0·78	0·92	oz./mushroom
final (12 weeks)	0·61	0·65	0·74	,,

Difference due to peat

Fruiting :	12 weeks	+13·3 (67%)	+9·6 (38%)	+8·7 (74%)	±1·7 mush./sq. ft.
Yield :	12 weeks	+ 4·4 (28%)	+4·8 (27%)	+6·7 (79%)	±0·7 oz./sq. ft.

The addition of peat brought the Yaxley soil into crop sooner, but slightly delayed the other two soils.

There were very marked differences between the crops obtained from the three soils, and all three were significantly improved by the addition of peat. The effect on the number of mushrooms was greatest in the soils which, when used alone, gave the smaller crops, but with the Yaxley soil the greater number of mushrooms produced with peat were very much smaller, and the proportional increase in total weight was about the same as with Selby soil, 28 and 27%. The Wisbech soil responded to peat by giving nearly twice as many mushrooms and maintaining the size.

The effects of peat observed in this experiment and with these soils should not be regarded as being applicable to other soils, nor even necessarily to the same soils in a different environment.

The house in which this experiment was carried out has a tendency to be dry, and this condition is acceptable because it reduces the incidence of disease. The addition of peat to soil increases its Water Holding Capacity which is likely to be beneficial under dry conditions.

The action of casing soil is unfortunately very complex, and all we can deduce from isolated experiments of this kind is the kind of difference which may exist between soils compared under similar house conditions and management, and the kind of change which can be produced by adding the same material, in this case peat, to each of them. It is worth noting that one soil gave a substantial increase in number of mushrooms, but with a partly compensating decrease in their size; while another soil gave a slightly greater increase in number, without any decrease in size. The difference in type of effect of adding peat might be due to the characteristics of the soils, or possibly might be due to the lower production from the latter soil when used alone.

As part of Experiment 23, 72 pots were used in a wide range factorial experiment on mixtures with three kinds of peat, used plain or with sand or Vermiculite, and with three depths of casing.

Types of peat	Mixtures	Depths
Sphagnum Medium sedge Fine sedge	Plain peat With sand 15 lb. per lb. of peat With medium Vermiculite 1 lb. to 1·5 lb. peat With coarse Vermiculite 1 lb. to 2 lb. peat	2·5 cm. (1 in.) 3·4 cm. (1⅓ in.) 5·0 cm. (2 in.)

As this was in the nature of a preliminary experiment results are not given in full detail. It is sufficient to say that neither type of peat nor of mixture gave any significant difference in time of first cropping or in number of mushrooms produced. The three peats gave different responses to mixing with sand or Vermiculite, as shown in Table 4. Sphagnum peat was improved by any of the mixtures, but the fine sedge peat was not. The addition of coarse Vermiculite to the medium sedge peat gave an increase in yield of doubtful significance.

Shallow layers of casing gave an earlier crop than medium or deep layers; medium depth gave the best yield, but the significance of the difference is doubtful. (Table 5).

Table 4. Yields from peat mixtures

Type of peat	Sphagnum	Medium sedge	Fine sedge	
		oz./per pot		
Peat alone	1·92	2·54	2·33	±0·2
with sand	2·33	2·12	2·37	
„ medium Vermiculite	2·79	2·79	2·17	
„ coarse Vermiculite ..	2·66	2·96	2·08	

Table 5. Effect of depth of peat casings

	Deep	Medium	Shallow	s.e.
First pinheads	80	78	75	±0·73 days from spawning
„ picking ..	86	85	81	„ „ „
Fruiting.. ..	6·8	8·0	7·2	±0·66 mushrooms/pot
Yield	2·3	2·6	2·4	±0·1 oz./pot

Experiment 24

The object of this experiment was to compare typical mixtures of peat-sand and peat-Vermiculite with each other and also with Yaxley soil. Unfortunately we did not sufficiently appreciate beforehand the differences in management of the two peat mixtures and soil with the result that the soil-cased beds were very late coming into crop and could not be compared with the two artificial mixtures.

The mixtures used were:

PV	Sphagnum peat	30 lb.
	Coarse Vermiculite	15 lb.
	Carbonate of lime	6 lb.
	Water	20 gallons
PS	Sphagnum peat	30 lb.
	Carbonate of lime	6 lb.
	Coarse sand	300 lb.
	Water	20 gallons

Beds were cased $1\frac{1}{4}$ and 2 inches thick, and half of the beds on each treatment received an additional watering after each two waterings of the whole house.

The experiment was brought to an early end and the yield was low because of pests and disease. Owing to staff illness this house was filled under difficulties and did not peak-heat very well, which might account for the unusually heavy attack of pests and disease. Cecid larvae and eelworms (*Ditylenchus* sp.) and a few mites, Brown Plaster Mould, *Panaeolus*, and "spiny-spored Yellow Mould" were observed during cropping or were present when the beds were emptied.

Table 6. Peat-Vermiculite and Peat-sand casings

	Peat-Vermiculite	Peat-sand
		s.e.
First pinheads	48	52 ±0·64 days from spawning
First picking	55	57 „ „ „
Fruiting—		
4 weeks	18·4	20·8 mushrooms/sq. ft.
total	21·0	24·7 ±1·3
Yield—		
4 weeks	7·9	8·6 oz./sq. ft.
total	9·2	10·2 ±0·8
Average size	0·42	0·39

Table 7. Number of beds in which foreign organisms were found

	Eelworms (*Ditylenchus*)	*Panaeolus* sp.	Yellow Mould	Total No. of beds in group
Peat-Vermiculite	17	5	3	20
Peat-sand ..	18	11	3	20
Yaxley soil ..	15	0	2	20
Probability ..		0·035		
Shelf 1	4	7	0	12
2	10	0	2	12
3	12	0	3	12
4	12	5	0	12
5	12	4	3	12
Probability ..	0·02	0·005		

Table 8. Number of beds (out of 60) in which Brown Plaster Mould and Yellow Mould were found.

	Brown Plaster Mould		
	found	not found	
Yellow Mould found ..	1 (4·55)	6 (2·45)	7
„ „ not found ..	38 (34·45)	15 (18·55)	53
	39	21	60

Probability 0·04

Figures in brackets give the expected distribution.

Their incidence showed some points of interest which are shown in Tables 7 and 8.

The probabilities that the observed distribution could have occurred by chance are given where they are statistically significant.

Panaeolus which has been observed occasionally as a weed fungus on mushroom beds here and elsewhere in the past, was very common on the beds cased with peat mixtures, but was absent from the soil-cased beds.

Eelworms were unevenly distributed between shelves, one shelf having $\frac{2}{3}$ of its beds free from eelworms, whereas on three shelves all 12 beds were attacked. Two shelves were free from *Panaeolus*, the other three having 33 to 60% of the beds affected.

There was a marked tendency for Brown Plaster Mould and the Yellow Mould not to occur in the same beds. (Table 8.) This could mean either that they are mutually competitive or antagonistic, or that the conditions which favour one do not favour the other.

The peat-Vermiculite casing gave a slightly earlier crop, but there was no significant difference in final yield. Extra watering gave slightly larger mushrooms, but the difference was of doubtful significance. There was no difference between $1\frac{1}{4}$" and 2" depth of soil.

Table 9. Effect of extra watering

Watering	" Normal "	Extra	
First pinheads	50	50	±0·64 days from spawning
First picking	57	56	,, ,, ,,
Fruiting—			
4 weeks	20·2	19·1	mushrooms/sq. ft.
total	22·8	22·8 ±1·3	,,
Yield—			
4 weeks	7·7	8·8	oz./sq. ft.
total	8·8	10·6 ±0·8	,,
Average size—			
total	0·39	0·46	oz./mushroom

Table 10. Effect of depth of casing

Depth of casing	$1\frac{1}{4}$ in.	2 in.	
First pinheads	48	51	±0·64 days from spawning
First picking	55	57	,, ,, ,,
Fruiting—			
4 weeks	21·3	17·9	mushrooms/sq. ft.
total	24·4	21·4 ±1·3	,,
Yield—			
4 weeks	8·3	8·2	oz./sq. ft.
total	9·7	9·7 ±0·8	,,
Average size	0·38	0·43	oz./mushroom

In another small scale experiment ten trays were used to compare mixtures of sphagnum peat-sand and sphagnum peat-Vermiculite, as shown in Table 11.

There was no difference in yield, but the peat-sand gave larger mushrooms and there was a curious difference in the intervals between first appearance of pinheads and first picking, 8 days on peat-sand, and 5 days on peat-Vermiculite. The difference was consistent in all the trays used. There was no such marked difference between the numbers, weights, or average size of the first flushes to account for this apparent difference in growth rate.

Table 11. Peat-sand and peat-Vermiculite

	A	F	
Sphagnum peat	20	20	lb.
Coarse Vermiculite		20	lb.
Sharp sand	22		lb.
Carbonate of lime	4	4	lb.
First pinheads	52	54	days from spawning
First picking..	60	59	„ „ „
Fruiting	15·8	18·8	mushrooms/sq. ft.
Yield	9·6	9·6	oz./sq. ft.
Average size	0·61	0·51	oz./mushroom

Effect of soil conditioners on cropping

A set of 20 shallow trays was used to test the effect of three soil conditioners on cropping. The active ingredients of the soil conditioners used were:—

A a maleic anhydride-vinylacetate copolymer.
B a hydrolysed polyacrylonitrile.
C carboxymethylcellulose.

In each case 1 lb. of the dry proprietary formulation was added to 100 lb. of the dry clay loam subsoil at Yaxley.

Table 12. Effect of soil conditioners

	Plain soil	+ 1% A	+ 1% B	+ 1% C	
First pinheads ..	49	50	50	50	days from spawning
First picking ..	60	60	59	63	„ „ „
No. of Mushrooms	34	25	19	19	±8 mushrooms per sq. ft.
Yield	9·4	8·0	5·5	7·3	±2·7 oz. per sq. ft.
Moisture content of soil at casing	20·3	19·6	18·2	20·5	%

The results in Table 12 show that none of these soil conditioners improved cropping in this experiment, and B gave a yield significantly lower than the untreated soil.

Experiment 25

Five shelves divided into twelve beds each were used to compare four sphagnum peat-sand mixtures and three watering treatments, as shown in Table 13.

The attempt to maintain the casing on the X and Y beds in a wetter state than that on the Z group, without actually measuring the quantitites of water applied, was unsuccessful.

The differences in physical properties and in watering treatment within the limits of this experiment had no apparent effect on fruiting. It appears that a wider range of physical properties and watering treatments must be tried, though these will be repeated under the drier conditions found in winter, when the heating system of the house is in use, and evaporation from the casing soil is greater.

Table 13. Composition of peat-sand casing mixtures and quantities of water added before casing

Mixture	Sorbex peat lb.	sharp sand lb.	carbonate of lime lb.	Water X gallons	Y gallons	Z gallons
A	18	20	$3\frac{1}{2}$	9	$4\frac{1}{2}$	$4\frac{1}{2}$
B	16	40	$3\frac{1}{4}$	8	4	4
C	12	80	$2\frac{1}{2}$	6	3	3
D	8	120	$1\frac{1}{2}$	4	2	2

AY, BY, CY, and DY received additional waterings during cropping, with the object of maintaining them as wet as AX, BX, CX, and DX respectively.

Table 14. Yields from three watering treatments on peat-sand casing mixtures

Watering treatment	X	Y	Z	
First pinheads ..	42	43	42	days from spawing
First picking ..	49	49	49	„ „ „
Fruiting—				
2 weeks	9·4	8·6	9·2	mushrooms per sq. ft.
4 „	16·6	16·0	16·0	„ „ „ „
8 „	30·6	29·9	30·7	„ „ „ „
12 „	37·6	36·0	37·2	„ „ „ „
Yield—				
2 weeks	0·44	0·40	0·44	lb. per sq. ft.
4 „	0·78	0·76	0·73	„ „ „ „
8 „	1·32	1·28	1·30	„ „ „ „
12 „	1·56	1·53	1·52	„ „ „ „

Table 15. Yields from four peat-sand casing mixtures

Soil mixture	A	B	C	D
Sphagnum peat	47	29	13	6
Sand	53	71	87	94 } % by weight
Peat : sand by volume ..	8 : 1	3·6 : 1	1·4 : 1	6 : 10
First pinheads ..	43	42	42	42 days from spawning
First picking ..	49	49	49	49 ,, ,, ,,
Fruiting—				
2 weeks	8·2	10·3	8·7	9·0 mushrooms per sq. ft.
4 ,,	15·1	17·9	15·6	16·1 ,, ,, ,, ,,
8 ,,	29·9	32·7	30·3	28·8 ,, ,, ,, ,,
12 ,,	36·5	39·3	35·9	36·2 ,, ,, ,, ,,
Yield—				
2 weeks	0·41	0·44	0·44	0·41 lb. per sq. ft.
4 ,,	0·74	0·78	0·76	0·75 ,, ,, ,, ,,
8 ,,	1·28	1·32	1·33	1·27 ,, ,, ,, ,,
12 ,,	1·58	1·52	1·52	1·52 ,, ,, ,, ,,

Addition of lime to peat casings

Considerable amounts of lime in some form must be added to peat for use alone or in mixtures for casing mushroom beds. It is also the practice of some users to add gypsum. A small scale experiment was set up using 50 pots to test the effect of using carbonate of lime, hydrated lime, and gypsum.

The casing mixture contained:
18 lb. of sphagnum peat
20 lb. of sharp sand
with the additions shown in Table 16.

Table 16. Effect of lime and gypsum in a peat-sand casing mixture

Mixture	Carbonate of lime	Hydrated lime	Gypsum	1st Picking	Final Yield		Final pH
	% of wt. of peat and sand, dry			days from spawning	mushrooms per pot	oz. per pot	
A	10%			58·9	16·9	7·1	7·6
P	20%			57·0	16·9	7·7	8·0
Q	10%	10%		56·2	13·6	7·3	9·1
R	10%	1%		58·0	19·2	7·4	8·7
S	10%		10%	57·6	16·2	6·4	7·6
	s.e. of mean			±0·8	±1·2	±0·5	

The results given in Table 16 show a slight reduction in fruiting where 10% of hydrated lime was used although the weight of crop was unchanged; the pH remaining high until the end of the crop. This was, of course, a very heavy dressing of lime, even for peat. 1% of hydrated lime and 10% of carbonate gave the greatest number of mushrooms, but there was no benefit from the addition of gypsum.

Experiment 26 was a factorial experiment in which four casing mixtures were used, each at three depths of casing material. The composition of the mixtures and results obtained with them are shown in Table 17; the results of varying the depth are in Table 18. The effect of depth was the same for all four mixtures.

Increasing proportions of sand progressively reduce the pore space (wet and dry) and moisture holding capacity of the casing mixtures. In this series the mixture G with 75% of sand by weight was the best. The mixture without sand (F) was inferior for the first two weeks of cropping, but after that the difference between F and G was not significant. G was always better than J (94% sand by weight) with H intermediate.

It may be relevant to note that these beds were in crop during October to December.

Table 17. Peat-Vermiculite mixed with varying proportions of sand

	F	G	H	J	
Sphagnum peat ..	10	10	10	10	lb.
Coarse Vermiculite	10	10	10	10	lb.
Sharp sand ..	0	60	160	360	lb.
Carbonate of lime	2	2	2	2	lb.
First pinheads ..	55	55	54	54	days from spawning
First picking ..	62	62	61	62	,, ,, ,,
Fruiting—					
2 weeks	33	41	33	32±2·4	mushrooms/sq. ft.
4 ,,	45	48	45	38	,,
6 ,,	52	54	50	42	,,
8 ,,	55	56	51	45	,,
Final (12)	60	63	58	51±2·4	,,
Yield—					
2 weeks	19·4	22·1	18·7	19·4	oz./sq. ft.
4 ,,	26·0	26·1	24·8	23·4	,,
6 ,,	29·9	30·1	27·9	26·7	,,
8 ,,	32·3	33·1	31·0	29·7	,,
Final (12)	37·3	39·1	36·2	35·2±1·2	,,

Table 18. Effect of depth of Peat-Vermiculite-sand mixtures

Depth of casing	1·5 cm. 0·6 in.	3 cm. 1·2 in.	4·5 cm. 1·8 in.	
First pinheads ..	53	54	56	days from spawning
First picking.. ..	61	62	62	„ „ „
Fruiting—				
2 weeks	36	39	29±2·1	mushrooms/sq. ft.
4 „	41	47	45	„
6 „	45	52	51	„
8 „	47	55	54	„
Final (12)	52	61	61±2·1	„
Yield—				
2 weeks	20·1	20·9	18·8	oz./sq. ft.
4 „	23·2	25·7	26·4	„
6 „	26·3	29·1	30·5	„
8 „	29·2	31·8	33·6	„
Final (12)	34·0	37·2	39·8±1·0	„

The deep cased beds were rather slower cropping at first, but after a few weeks they caught up, giving as many mushrooms and a greater final yield than the medium depth. 1·5 cm. (0·6 in.) of casing was not enough in this experiment, and the best result was obtained from 4·5 cm. (1·8 in.).

MICROBIOLOGY DEPARTMENT

D. G. Gandy

Advisory work

One hundred and fifteen samples were received and examined during 1952. Nematodes and Cecid larvae again were the most frequently encountered pests, but among the fungal diseases and competitors the emphasis has switched from the parasitic diseases and "Truffle" to Yellow Mould. This latter name is not meant to refer to any one particular fungus but is used as a general description of yellow moulds found in compost whose identity and status is open to question (see page 38).

The following is a list of the more important organisms found in samples together with the number of times each was identified.

Parasitic on mushrooms

Verticillium malthousei	1

Competitors or Invaders

Papulaspora byssina	8
Yellow Mould, Verdigris or Mat disease	17
Scopulariopsis fimicola	6
Pseudobalsamia microspora	2
Chaetomium sp.	8
Oedocephalum fimetarium	1
Trichoderma viride	5
Botrytis gemella	1
Peziza sp.	1
"Bacterial pit"	6
"Bacterial rot"	7
Aspergillus sp.	1
Monilia sp.	2
"Rose comb"	1
Corticium sp.	1
"Geotrichum"	2
Panaeolus sp.	1

Pests

Nematodes (parasitic and saprophytic)	37
Cecid larvae	17
Mites	7
Phorid larvae	7
Springtails	1
Sciarid larvae	1
Enchytraeids	3

Experimental work

Disinfection procedures commonly employed between crops include the use of formalin, mixed xylenols and live steam.

An experiment was set up to demonstrate the relative merits of these methods. Eight-inch plastic pots were filled with compost, spawned and cased. Small pieces of unplaned wood were inoculated and then subjected to the various disinfection procedures. A piece of wood was buried in each pot with the exception of those infected with spores of *Mycogone perniciosa* which were placed on the surface of the casing soil. The pots were cropped for eight weeks, then turned out and examined. A summary of the results is given in Table 19.

Table 19. Comparison of three disinfectant procedures

Disease	Control		Treatment 2% mixed xylenols		1% Formalin		Steam Heat 55° C.	
Cecids.. ..	+	+	+	—	+	+	+	—
Eelworms ..	+	+	+	+	+	—	+	—
Yellow Mould (spiny spored)	+	+	+	+	+	+	+	+
Mycogone perniciosa	+	+	+	+	—	—	—	+
Verticillium malthousei ..	+	—	—	—	—	—	—	—

\+ denotes pest or disease present.
— „ „ „ „ absent.

As a check on the efficiency of steam disinfection carried out in our cropping houses, infected material of various kinds was placed in the houses before steaming and examined afterwards.

Treatment—live steam and formalin.

A. Compost infected with mites (*Pigmaeophorus* sp. and *Histiostoma* sp.), springtails and nematodes was placed in the following positions:—

(1) loose pieces on perforated zinc on a tripod.
(2) loose pieces on an enamel tray.
(3) packed tightly in an enamel tray.

B. Agar plates inoculated with spores of *Mycogone perniciosa*, *Dactylium dendroides* and *Verticillium malthousei* were freely exposed to the atmosphere inside the houses. Control plates inoculated with spores of the same fungi were not exposed. The results are shown in Table 20.

Table 20. Treatment with live steam and formalin

	Position		
	1	2	3
Mites	+	++	+
Springtails ..	none found	+	none found
Nematodes ..	—	+—	++
M. perniciosa	Exposed spores failed to germinate. Controls developed normal colonies.		
D. dendroides			
V. malthousei			

\+ denotes pest or disease present.
— „ „ „ „ absent

These results should not be interpreted as meaning that steam and formaldehyde disinfection is useless, but they do demonstrate the importance of thorough penetration by the steam and formalin mixture. This was not possible in the tightly packed compost nor in the compost laid on a tray. Another factor which must be borne in mind is that the houses in which the disinfections were carried out were not well insulated, and consequently much of the steam escaped.

The Effect of Ultra Violet Radiation

No further experiments were carried out on the effect of ultra violet radiation on mushrooms attacked by " Bacterial Pit." The effect of such radiation on the spore germination of fungi causing mushroom diseases and others frequently found in mushroom houses was however investigated.

Plates of 2% malt agar were inoculated with spores of the following fungi:—

Dactylium dendroides
Mycogone perniciosa
Verticillium malthousei
Trichoderma viride
Penicillium sp.

These plates were exposed to U.V. radiation of 0·3 micro watts per sq. cm. for various periods namely:—

8 hours per day for 1, 2, 3 days.
16 hours per day for 1, 2, 3 days.
24, 48, 72 hours.

The results are shown in Table 21.

Table 21. Germination of spores after exposure to U.V. radiation at 0·8μwatts/sq. cm.

No. of days irradiated	Length of each exposure to radiation: 8 hours			16 hours			24	48	72 hrs.	Control 0
	1	2	3	1	2	3				0
	Plates examined after 24 hours									
Trichoderma	—	—	—	—	—	—	—	—	—	+
Dactylium	+	+	+	+	+	+	+	+	+	+
Verticillium	—	—	—	—	—	—	—	—	—	+
Mycogone	—	—	—	—	—	—	—	—	—	—
Penicillium	+	+	+	+	+	+	+	+	+	+
	Plates examined after 48 hours									
Trichoderma	+	+	+	+	+	+	+	+	+	+
Dactylium	+	+	+	+	+	+	+	+	+	+
Verticillium	+	+	+	+	+	—	+	—	—	+
Mycogone	—	—	—	—	—	—	+	—	—	+
Penicillium	+	+	+	+	+	+	+	+	+	+
	Plates examined after 72 hours									
Trichoderma	+	+	+	+	+	+	+	+	+	+
Dactylium	+	+	+	+	+	+	+	+	+	+
Verticillium	+	+	+	+	+	+	+	+	+	+
Mycogone	—	—	—	+	—	—	+	—	—	+
Penicillium	+	+	+	+	+	+	+	+	+	+

\+ denotes spores had germinated.

— denotes spores had not germinated.

Spore germination was not inhibited by U.V. radiation at this strength, up to 72 hours continuously, and germination occurred evenly all over the plates.

The strength of irradiation was therefore increased to 3·6 micro watts/sq. cm., for single periods of 8, 16, and 24 hours. At this strength spore germination of these five species was generally inhibited. A few spores of *Trichoderma*, *Dactylium*, and *Penicillium* germinated after this stronger irradiation but they were all in clumps of spores and had probably been protected from the full intensity of the radiation by other spores in the clumps.

Studies on " Bacterial pit "

The bacterial diseases of mushrooms have been studied by a number of workers, notably Matruchot (1909), Tolaas (1915), Kligman and Penny (1943) and Wood (1950, 1951). They have distinguished various conditions associated with the presence of bacteria and have assigned to them such names as " La Goutte ", " Weeping disease ", " Bacterial spot ", and " Bacterial pit ". Opinions have differed as to whether the last two are different phases of the same disease, but experimental inoculations with bacteria have resulted in the spotting described by Tolaas for " Bacterial spot " whereas the establishment of pitting which is so characteristic of " Bacterial pit " has not been achieved.

The cause of this condition is not known, nor is it certain that bacteria are primarily responsible for it although bacteria are always present in pits on the cap, and in severe attacks are to be found in large colonies on and between the gills.

Incidence of " Bacterial pit "

" Bacterial pit " can cause serious loss when it becomes established early in the life of a mushroom crop, but examination of the records of four cropping experiments carried out at different seasons shows that at the Research Station it does not appear before about 60 days after the appearance of the first pinheads, that is to say during the 5th to 7th flush.

Experiments on " Bacterial pit "

The first experiment was carried out to ascertain if ultra-violet radiation would control the spread of " Bacterial pit " and the results are described in the 1952 Annual Report.

The next experiment repeated some of the work carried out by Wood (1951). Six boxes were spawned and cased with unsterilised soil. Each of three boxes were divided into half and on one half was placed the caps of pitted mushrooms, while the other half was sprayed with an aqueous suspension of bacteria from pitted mushrooms. The control boxes were similarly divided into halves, and sprayed with distilled water or had healthy mushroom caps placed on them. The first treatment was carried out before pinheads appeared, and a second treatment was given when mushrooms were on the boxes. No pitting occurred in any box, thus confirming the findings of Wood.

If bacteria are the primary cause of pitting, then it follows that the casing material is a very likely source of these bacteria, and a possible method of control is by sterilisation of the casing. An experiment was therefore designed to explore this possibility. Three types of casing were used, Yaxley subsoil and lime, sphagnum peat and lime, and sand. The sand was included since it can be more effectively sterilised than either soil or peat. All casings were sprayed with a heavy suspension of bacteria from pitted mushrooms and half of each casing material was sterilised by treatment with formalin. The results were inconclusive, there being slightly more pitted mushrooms with unsterilised casings. The results are summarised in Table 22.

Table 22. Incidence of " Bacterial pit "

Treatment	Healthy		Diseased		Treatment	Healthy		Diseased	
	No.	Wt. oz.	No.	Wt. oz.		No.	Wt. oz.	No.	Wt. oz.
Unsterilised soil	98	71½	16	10¾	Sterilised soil	31	33	—	—
Unsterilised sand	57	35¾	1	¼	Sterilised sand	59	50¼	1	1¼
Unsterilised peat	88	71	1	½	Sterilised peat	140	84½	3	1½

Another experiment was carried out to investigate the possibility of airborne infection. Part of an infected bed was dug out and into the prepared space were placed six boxes newly cased. They were left in position until cropping started three and a half weeks later. Six control boxes were kept in a disease free house and the treated boxes were later placed with them for the cropping period. During the first four days of cropping, one of the treated boxes produced three very heavily pitted mushrooms, but later mushrooms were quite healthy.

Injection of the caps of mushrooms with bacteria taken from pits has also failed to produce typical pits.

Bacteriological Studies

Isolations of bacteria from pits still covered by the outer membrance of the mushroom cap are being made and the cultures thus obtained are being studied. This programme of work is still in its early stages but the bacteria so far isolated appear to belong to the genus *Pseudomonas*, probably *Ps. fluorescens*. Their average measurements are 0·9μ x 0·4μ, they are motile, Gram negative, non-sporing, and weak fermentors of carbon compounds. Examination of the pitted tissues indicates that bacteria are only present in the pit and not in the surrounding intact tissue. None of the bacteria isolated are capable of rotting mushroom tissue. Experiments by other workers show that the ability to decompose mushroom tissue is rapidly lost in pure culture but experiments in which gill and cap tissue have been inoculated with bacteria taken directly from pits have failed to produce any rotting.

Yellow Moulds

Cultures of a dozen yellowish moulds found in mushroom beds in the U.S.A. have recently been received from Dr. L. R. Kneebone, Pennsylvania State University. Preliminary studies of these moulds indicate that they are different from the yellow moulds most commonly found in compost in this country. It is hoped to examine also moulds isolated on the Continent and thus to obtain some indication of how far the results of investigations on " Verdigris " and " Mat disease " carried out in other parts of the world are applicable also to this country.

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MUSHROOM DISEASE NAMES

R. L. Edwards and D. G. Gandy

There is considerable ambiguity in use of the names Vert-de-gris (Verdigris) and Mat disease to describe some yellowish fungi which grow in mushroom beds, and the damage to the crop associated with their presence.

There are several aspects of this ambiguity.

1. The name Vert-de-gris was applied by Costantin (1892) to a disease caused by *Myceliophthora lutea* (Cost). Costantin and Matruchot (1894) considered that *M. lutea*, although it can grow saprophytically on other media, behaves as a true parasite of the mushroom mycelium.

In mixed cultures of *Agaricus hortensis* and *M. lutea* they observed:

1. that *M. lutea* grows more rapidly and more abundantly than when alone.
2. that its hyphae creep over the strands of the spawn and form an intricate tufted network.
3. that the spawn appears to suffer from the effects of its proximity and develops less efficiently.

The name Vert-de-gris has since been applied at times to any yellowish fungus found in a mushroom bed, and to certain forms of abnormal growth of mushrooms believed to be due to one or more of these fungi. *Myceliophthora sulphurea* has also been identified in compost under similar circumstances, in U.S.A.

As Dr. J. W. Sinden rightly pointed out in the course of discussion at the Second International Conference at Gembloux, it is incorrect to use the name Vert-de-gris for any fungus other than *M. lutea;* since it is only possible to distinguish *M. lutea* from other fungi often found in mushroom beds and to identify it with certainty, by examination under the microscope, the use of the popular name Vert-de-gris is unjustified and may be seriously misleading in any particular case until its identity has been established in this way. When that has been done the specific name *M. lutea* can just as well be used, and Vert-de-gris becomes more or less redundant.

2. The name " Mat disease " was originally used by Manns (1947) to describe " a severe form " of the disease due to *M. lutea*, in which the fungus forms a mat just below the casing soil. Manns refers to two forms of *M. lutea*, one with smooth chlamydospores as described by Costantin, and one with chlamydospores having ebullitions or spines on the margins.

This name has likewise been applied to other conditions superficially similar in appearance, often without identification of the fungus present.

3. The causal relationship between the partial or complete crop failure, which usually prompts an examination of the compost, and the presence of one or more of these yellowish fungi has not been rigorously proved

by transfer of the fungus, production of symptoms, and reisolation of the fungus.

4. The opinion has been expressed that the presence of these fungi and the reduced crop may both be due to other primary faults in the compost.

If this is so there are various possibilities, applying to any of the fungi concerned:

1. the damage to crop may be due entirely to the primary faults in the compost
2. the damage may be due to direct attack on the mushroom mycelium by the invading fungus, such attack only being possible because the primary faults weaken the mushroom and/or enable the invading fungus to grow
3. the damage may be due to competition by or toxic products of the invading fungus, the invasion being made possible because of the primary faults in the compost.

A name such as Vert-de-gris or Mat disease is useful only so long as it can only refer to one organism, or to a group of organisms producing the same effects, and therefore is unambiguous.

As there are undoubtedly several yellowish fungi which are found in mushroom composts and the damage caused by each of them is uncertain, the use of a single name, implying a definite identity for all of them, is misleading.

Until more information is available we therefore propose to discontinue use of the names " Verdigris " or " Vert-de-gris ", and to describe fungi of this group as " Yellow Moulds " unless and until a particular species has been identified. A popular name is needed, but it should not suggest relationships which are still doubtful. " Yellow Mould " as applied to these fungi found growing in mushroom composts is really as descriptive a name as our limited knowledge of some of them justifies.

The name " Vert-de-gris " (or " Verdigris ") should only be applied where the fungus *Myceliophthora lutea* has been identified microscopically, until the *specific causal relationship* between this fungus and other characteristic symptoms, e.g., the abnormal forms of growth of the mushroom described by Wood (1950), has been proved by inoculation experiments with suitable controls; and until the specific causal relationship already mentioned has been established, abnormal forms of growth of mushrooms should also be given suitable descriptive names which do not imply an unproved relationship to an alleged causal organism.

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RESULTS OF A SURVEY OF MUSHROOM GROWING PRACTICE IN GREAT BRITAIN

R. L. Edwards

During 1952 a form of questionnaire was sent out to mushroom growers in Britain, and a few overseas, who were members of the Mushroom Growers' or the Research Association. Growers were asked to complete the form, indicating which of several given alternatives they practised with regard to source of manure and composting; casing soil and additions of lime, ashes, peat; ventilation and heating; and the pests and diseases they found troublesome. The survey had two objects, to provide a check on the subjects which need research, and to see whether any of the common cultural practices were associated with particular pests and diseases.

In making a survey of this kind where the growers themselves supply the data, there cannot be quite the same degree of certainty about the identification of pests and diseases as if it is done by trained plant pathologists; although of course in many cases the identification would have been made by pathologists in the first place. There are also " fashions " in disease, and it is uncertain how far these reflect a real wave of a particular disease, or how far they merely indicate a tendency to blame any trouble on the disease last heard of; certainly waves of particular pests and disease do occur. These uncertainties cast some doubt on any conclusions drawn from a survey of this kind, but one would expect the uncertainty or error, if any, to apply evenly to all groups of growers. For example it is not to be expected that a particular disease would be spuriously " fashionable " among growers who use heavy horse manure, and not among those using racing stable manure; there is no reason why differences of that kind in cultural practice should produce a bias in reports of pests or disease.

Of the 77 questionnaire forms returned, a few were discarded, either because the growers were abroad or because they were only just starting to grow mushrooms and had neither established their methods nor experienced disease. Some results relating peak-heating to the incidence of pests and disease were described at the Second International Conference at Gembloux, in June, 1953. They are summarised in Table 23, the probability that any of the observed distributions could occur by chance being given.

The heavy incidence of Brown Plaster Mould among tray growers using live steam is noteworthy, and did not occur to the same extent where live steam was used to peak-heat shelf beds (Table 24).

Another factor which appears to have some influence on disease is the kind of manure used. Here again there is an element of personal judgment in describing the manure, but one of the results is rather striking (Table 25). Yellow moulds were not reported from any of the twelve farms in the survey, where only heavy manure was used, compared with 56% of those using racing stable manure unfortified, and the incidence was slightly less in enriched racing stable manure. There was also a tendency for Truffle to occur less on farms using richer manure (Table 26).

Table 23. Number of farms where pest or disease was reported

	Using live steam to peak heat	Peak-heating without live steam	Not peak-heating
With Yellow Mould ..	.. 4 (17%)	15 (43%)	6 (43%)
Without Yellow Mould	..19 (83%)	20 (57%)	8 (57%)
Yellow Mould was less common where live steam was used (P=3·5%)			
With nematodes ..	.. 5 (22%)	7 (20%)	1 (7%)
Without nematodes ..	..18 (78%)	28 (80%)	13 (93%)
Incidence of nematodes was not significantly altered by either method of peak-heating (P=25%)			
With White Plaster Mould ..	7 (30%)	10 (29%)	3 (21%)
Without White Plaster Mould	16 (70%)	25 (71%)	11 (79%)
Incidence of White Plaster Mould was not altered by either method of peak-heating.			
With Cecid larvae ..	.. 9 (39%)	14 (33%)	1 (7%)
Without Cecid larvae ..	..14 (61%)	21 (67%)	13 (93%)
Incidence of Cecid larvae was greater where peak-heating by either method was practised (P=2%)			
With Brown Plaster Mould ..	12 (52%)	9 (25%)	2 (15%)
Without Brown Plaster Mould	11 (48%)	26 (75%)	12 (85%)
Incidence of Brown Plaster Mould was greatest where live steam was used for peak-heating (P=0·5%)			

Table 24. Incidence of Brown Plaster Mould and method of peak-heating in trays and shelves

	Brown Plaster Mould causing losses	Brown Plaster Mould a nuisance	No Brown Plaster Mould	
Tray growers				
Peak-heating with live steam	3 (37·5%)	3 (37·5%)	2 (25%)	8
Peak-heating without steam..	0	1 (20%)	4 (80%)	5
Not peak-heating	0	1 (33%)	2 (67%)	3
Shelf growers				
Peak-heating with live steam ..	0	0	3 (100%)	3
Peak-heating without steam..	2 (12%)	1 (6%)	13 (82%)	16
Not peak-heating	0	1 (20%)	4 (80%)	5
	5	7	28	40

Table 25. Effect of type of manure on number of farms where Yellow Mould was reported

	Heavy	Racing stable	Racing stable plus activators
Yellow Mould ..	0 (0%)	9 (56%)	3 (38%)
No yellow Mould ..	12 (100%)	7 (44%)	5 (72%)

Yellow Mould was less common where heavy manure was used (P=1%)

Table 26. Number of farms where Truffle occurred.

	Heavy or fortified manure	Racing stable manure	
Truffle reported ..	3 (8%)	8 (50%)	11
No Truffle ..	17 (92%)	8 (50%)	25
	20	16	36

Truffle occurred on more farms using racing stable manure than where richer manure was used. (P=2·9%).

Table 27. Effect of steaming casing soil on number of farms where *Mycogone* occurred

	Soil steamed	Unsteamed
Mycogone	1 (10%)	28 (49%)
No *Mycogone*	9 (90%)	29 (51%)

Mycogone was less common where casing soil was steamed (P=2·6%)

Table 28. Number of farms where Bacterial Pit occurred.

Casing soil limed with	Hydrated lime	Carbonate of lime	
Bacterial Pit reported..	10 (29%)	15 (56%)	25
No Bacterial Pit ..	24 (71%)	12 (44%)	36
	34	27	61

Bacterial Pit occurred on more farms using carbonate of lime in their casing soil than where hydrated lime was used. (P=3·3%).

The figures in Table 27 support the practice of steaming casing soil to control *Mycogone*. The incidence of the other common diseases and pests seemed to be unaffected by steaming the soil.

Bacterial Pit occurred on a larger proportion of farms where carbonate of lime was used to neutralise the casing soil rather than hydrated lime (Table 28).

Some of the information obtained from this survey can be applied to reduce the incidence of disease.

Where there are both good and bad effects, such as with the use of live steam for peak-heating, it may be possible to modify the process, or to adopt other measures to control the diseases which arise. In this particular case the increase in Brown Plaster Mould which occurs especially on trays peak-heated with live steam might be prevented by having a larger gap between trays, say two inches, and really keeping it clear, and by cooling down more slowly, so that there is less chance of forming a wet layer on the surface of the compost. For Cecid larvae insecticides would have to be used, although none has yet been found to give complete control. Both DDT and BHC in the form of sprays kill large numbers of them. They often survive from one crop to the next; phenolic disinfectants are better than formalin for cleaning after an attack of Cecid larvae, and dipping trays or boards is better than spraying. The composting floor should also be disinfected in the same way.

Of the other results, steam sterilisation has long been used to destroy *Mycogone* in casing soil. It is interesting that it apparently did not prevent attacks by any of the other common diseases.

It is not practical to advise all growers to use heavy manure but those who do not might reduce their disease troubles by fortifying their manure up to " heavy " standard.

The apparent effect of hydrated lime on Bacterial Pit is interesting. One of the greatest sufferers from Bacterial Pit adds hydrated lime to the soil, but normally does this so long before use that it is carbonated long before it reaches the beds.

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Published by the Mushroom Research Association Ltd.
Yaxley, Peterborough, England

Printed by W. S. Maney & Son Ltd., Russell Street, Leeds 1